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SUPPLEMENT TO THE AMERICAN EPHEMERIS, 1900.

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TOTAL ECLIPSE OF THE SUN MAY 28, 1900.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF THE NAVY.

WASHINGTON:
BUREAU OF EQUIPMENT.
1900

SUPPLEMENT TO THE AMERICAN EPHEMERIS, 1900.

TOTAL ECLIPSE OF THE SUN MAY 28, 1900.

Prepared by direction of C. H. DAVIS, Capt., U. S. Navy, Superintendent U. S. Naval Observatory,

BY

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WASHINGTON:
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PREFACE.

In issuing these suggestions concerning observations of the Total Eclipse of the Sun on May 28, 1900, it is hoped that some valuable scientific observations may be secured which would otherwise be lost.

The Observatory wishes to make its report on the Eclipse as valuable as possible, and it will gladly include any results, sketches, photographs, observations of contacts, or any observations of sufficient merit to make them worthy of preservation.

C. H. DAVIS,
Captain, U. S. N.,
Superintendent Naval Observatory.

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PART I.

SUGGESTIONS FOR OBSERVING THE ECLIPSE.

TOTAL ECLIPSE OF THE SUN, MAY 28, 1900.

The suggestions in this paper are intended to direct the attention of observers to those phenomena of the eclipse, observations of which can be made, either with the naked eye or with instruments, by those of limited experience or entirely inexperienced. The subject naturally divides itself into four heads: 1. Sketches of the corona with the naked eye. 2. The Moon's shadow bands. 3. Photographs of the corona. 4. Observations of the times of the contacts.

In addition to the drawings of the corona and observations of the shadow bands, special attention is asked to the observations of the times of beginning and end of totality on page 18, careful observations of which, with instruments of very modest dimensions or with the naked eye, will have a special value in correcting the Moon's position.

I.—SKETCHES OF THE CORONA WITH THE NAKED EYE.

The duration of totality will be short, varying from 1^m 12^s in the neighborhood of New Orleans to 1^m 40^s near Norfolk. Preliminary preparations therefore should be carefully made, and the necessary skill and quickness acquired by practice on artificial models. Those who expect to make a sketch of the corona unaided will have to confine their attention to sketching the outlines or to some other particular feature, otherwise there will result hasty and inaccurate work. Cooperation of groups of from two to five sketchers, as practiced in the last eclipse in India, 1898, is strongly commended by the successful drawings then made.

In any case, whether sketching singly or in co-operation with others, there should be prepared a diagram to form the basis of the drawing of the corona. A sheet of paper of convenient size, about 9 by 12 inches, should have drawn upon it a black disk $1\frac{1}{4}$ inches in diameter, to represent the Moon, with straight lines radiating from the center at angles of 30°, as shown in Plate I. The positions of the various parts of the corona, as seen projected against the sky, are best referred to a vertical line obtained by mounting a plumb line so that it is seen hanging over the Moon's center. The diagram upon which the drawing is to be made is to be placed upon any convenient support, so that the line marked "Top" "Bottom" shall be in the plane of the plumb line, the top part corresponding to the top of the string.

Others might find it more easy to estimate the angular positions by dividing the diagram into four quadrants, as the actual position of the parts of the corona as seen in the sky will have to be estimated from the vertical plumb line and an imaginary horizontal line perpendicular to the plumb line.

On Plate I is shown the outline method of sketching in the forms of the inner and outer corona, where the principal stress is laid upon the accuracy of position and form.

It is a reproduction of a drawing by Mr. E. J. STONE in 1874, at that time Director of the Royal Observatory, at Cape of Good Hope. *aaa* shows the outer corona, the part at *a'* indicating a faint and indefinite boundary; *bbb* shows the inner corona. This sketch forms no part of the diagram to be used in the coming eclipse, but is placed on the diagram only as an illustration of the method. The dimensions of the various parts of the eclipse can be made with accuracy by estimating them in terms of the Moon's diameter as a convenient unit.

For the benefit of those who may wish to try the co-operative plan of sketching, the following hints with but little modification are taken from the report of the British Astronomical Association on "*Indian Eclipse, 1898:*"

• "HINTS FOR MAKING DRAWINGS OF THE CORONA.

"1. The party should consist of at least five persons—four to sketch details of single quadrants, and one (the leader) to sketch rapidly the general features of the corona. The leader will then be able to correct and supplement the work of the quadrant sketchers, when producing the combined sketch. This must be done on the same day, immediately after the eclipse, and in consultation with the whole party; and all the drawings should be photographed as soon as completed. The drawings themselves, even if faulty, should not be touched after completion.

"2. The party should practice together beforehand, each one sketching his own proper quadrant from a corona drawing suspended at the angular height of the Sun. The time of exposure of the drawing should be slightly less than the known duration of the eclipse. By rotating the drawing it may be made to serve for four sketches. The drawing must be well illuminated and clear, but must not be large. The Sun and Moon are small objects to the eye, and a large drawing would not give useful practice.

"3. Experience shows that Mr. GREEN'S suggestion as to materials, white chalk on purplish-blue paper, is an admirable one. For practicing, brown paper serves very well if blue paper is scarce.

"4. It is important always to practice on the same scale as the final sketch is to be made. It has been found that a silver half dollar ($1\frac{3}{8}$ inches in diameter), is a very convenient size for the black body of the Moon, and this may be always at hand. A circle, being drawn round the half dollar, is bisected vertically and horizontally, and the diameters are produced across the paper. The sketcher has a plumb line (a bunch of keys at the end of a string will do), with which he divides his model corona vertically as he looks up at it, and he guesses at the corresponding horizontal division. His quadrant thus fixed, he proceeds to sketch it. When the time is called the leader redraws all four quadrants in one combined sketch, and by comparison with the original, the habitual faults of the sketchers are detected, and in the course of a few practices will disappear.

"5. The position of any planet or high-magnitude star very near the Sun at the time of eclipse should be accurately ascertained, and its distance measured in terms of the Moon's diameter (taken as half a degree), as these facts when made familiar to the whole party will check the supposed direction and extent of any long streamers of the corona.

"6. On eclipse day the sketchers should avoid fatiguing their eyes by too much observation of the preceding partial eclipse, and should rest the eyes for the last five minutes before totality, absolutely. It would be well to close them for the last minute, and open them by a signal at totality. Attention should be paid to the extreme extent and to the color of the corona at the moment of beginning to draw, when the eye is at its freshest, and consequently is better able to observe these points than after gazing at the very bright inner parts of the corona."

It should not be inferred from the emphasis laid upon the number five that co-operation between two or three observers would not have an advantage over the method of making a sketch unaided.

II.—THE MOON'S SHADOW BANDS.

The Moon's shadow is bordered by diffraction bands of alternate light and shade which are visible on any white background, and last about a minute before and after totality. At the eclipse expedition to the Caroline Islands in 1883 they were successfully observed, and the simple method adopted there is recommended. A white sheet, table spread, or other large piece of white cloth, is spread upon the ground and securely fastened, the edges lying north and south and east and west. The observer should be provided with a long rod, which he will lay upon the sheet either parallel or perpendicular to the shadow bands as they move rapidly across the sheet, in order to get their direction. A similar one should be used for the line succeeding totality, as the directions differ widely. Measure as accurately as practicable the direction of the two positions of the rods, using a compass or other instrument in order to get their azimuth or bearing. A second observer, provided with a watch should try to count the number of bands per minute, and estimate carefully their distance apart in inches as they move across the white surface. In the report upon this phenomenon, in giving the direction of the rods with reference to the compass points, it should be stated whether they were placed parallel or perpendicular to the lines.

III.—PHOTOGRAPHS OF THE CORONA.

The results of the Indian eclipse expedition in 1898 have shown that photographs of great scientific value may be obtained with instruments of moderate dimensions. Indeed for many purposes two of the most valuable series were secured by an amateur—one with a DALLMEYER stigmatic lens, $1\frac{1}{2}$ inches aperture and 9 inches focus, showing a greater extension of the corona than had ever before been obtained by photography; the other, an instrument of much larger dimensions, and provided with a driving clock, carrying the two cameras in combination, both being manipulated by a lady, the wife of one of the members of the expedition. Another valuable series was secured by an amateur with a DALLMEYER rectilinear lens of $2\frac{1}{8}$ inches aperture, only the back lens being used, which gave an equivalent focus of $32\frac{1}{2}$ inches. This apparatus was a home-made affair, and to show the ease with which instruments of great value may be provided, a description of the instrument is quoted:

My lens was a DALLMEYER rapid rectilinear, the back lens of which only was used. As thus used it had an aperture of $2\frac{1}{8}$ inches and a focal length of $32\frac{1}{2}$ inches. The camera was home-made, being nothing more than a long, light-tight box, fitted to carry half-plate slides. Along the top of the camera was fixed a brass tube parallel to the major axis of the camera, having cross hairs fixed at the lens end. A few inches from the other end was placed a little mirror, so that when standing over the camera a person by looking into it could see the cross hairs up the tube, and also see when the Sun was centrally on them. In the photograph, I am looking into this mirror as I turn the tangent screw. An ordinary screw held the camera toward the lens end fixed to the stand, while toward the plate end of the camera was fixed a long camera screw, which, acting as a tangent screw, enabled me to follow the Sun and keep it on the cross hairs.

As the results obtained at this eclipse were of such a striking nature and represent in many respects such a distinct advance over any work of that character hitherto done, the suggestions in this paper are confined almost entirely to the material obtained from the report of "*The India Eclipse, 1898.*"

The following table gives the instruments employed, their dimensions, the ratio of $\frac{f}{a}$, the actual exposure, and the equivalent exposure using a lens of $\frac{f}{a} = 15$ as the basis. In the table no allowance has been made for the rapidity of the plates used.

Table of Instruments and Results, India Eclipse, 1898.

No. of photo.	Series.	Equivalent focus f .	Aper- ture a .	$\frac{f}{a}$	Expo- sure time.	Equivalent exposure $\frac{f}{a}=15$	Kind of plate.	Remarks.
1-2	I.	96	1.67	57	Sec. 1	Sec. 0.067	X rapid.	
3	II.	32.5	2.1	15	$\frac{1}{4}$	0.25	X rapid, heavily backed.	
4-5	I.	96	1.67	57	5	0.33	X rapid.	
6	III.	26	1.2	22	1	0.46	X rapid, isochro- matic.	
7	II.	32.5	2.1	15	$\frac{1}{2}$	0.50	X rapid, backed.	
8	III.	26	1.2	22	2	0.93	X rapid, isochro- matic.	
10	II.	32.5	2.1	15	1	1.00	X rapid, backed.	
11	IV.	60	4.1	14.7	1	1.04	Ordinary.	
12	V.	71	4.25	16.7	$1\frac{1}{2}$	1.20	Ordinary.	
13-14	I.	96	1.67	57	20	1.32	X rapid (?).	
15	III.	26	1.2	22	3	1.40	Ordinary, backed.	
16	III.	26	1.2	22	4	1.90	Ordinary, backed.	
17	II.	32.5	2.1	15	2	2.00	X rapid, backed.	
18	IV.	60	4.1	14.7	2	2.20	Ordinary.	
20-21	II.	32.5	2.1	15	4	4.00	X rapid, backed.	
22-23	VI.	9	1.5	6	1	6.25	X rapid.	
24	V.	71	4.25	16.7	9	7.25	Ordinary.	
26	V.	71	4.25	16.7	30	24.2	Ordinary.	
27-28	VI.	9	1.5	6	5	31.2	X rapid.	
29-30	VI.	9	1.5	6	20	125.0	Triple-coated.	

One other series of especial interest not included in the table was taken with a 6-inch lens of 40 feet focus ($\frac{f}{a}=80$). An exposure of half a second showed the very beginning of the eclipse with a range of small prominences nearly around the limb.

The results contained in the above table furnish the most recent and instructive experiences for the settlement of the difficult problem of eclipse photography—the time of exposure. The long exposure of 20 seconds with a lens $1\frac{1}{2}$ inches and 9 inches focal length is more than seven thousand times as great as the equivalent exposure of $\frac{1}{2}$ second with a 6-inch lens of 40 feet focal length, assuming that equivalent exposures vary inversely as $(\frac{f}{a})^2$. Both of these photographs were successful in attaining their respective objects. The first shows the very beginning of the eclipse with a range of small prominences. The second shows a greater extension of the corona than ever before obtained by photography.

The results of the table may be briefly summarized as follows: The equivalent exposure is given for $\frac{f}{a}=15$.

(a) Exposures for the brighter portions of corona.

1. The one-second plate of Series I, equivalent exposure 0.067 seconds, shows the prominences and a distinct ring of the corona 2' to 3' in height.

2. The next plate in order of light efficiency is the first of Series II, exposure $\frac{1}{4}$ second, equivalent exposure $\frac{1}{4}$ second. Here the exposure of inner corona up to 3 minutes from the limb is full. The prominences are much over-exposed. The fainter parts of the corona come out distinctly and roots of the great coronal rays are visible one diameter from the limb.

3. Nos. 4 and 5, Series I, exposure 5 seconds, equivalent exposure $\frac{1}{3}$ second, show a considerable development of the corona.

4. Nos. 7 and 10 of Series II, exposures $\frac{1}{2}$ and 1 second, equivalent exposures $\frac{1}{2}$ and 1 second, and No. 13 of Series I, exposure 20 seconds, equivalent exposure $1\frac{1}{3}$ seconds, do not greatly extend the dimensions of the corona above 4 or 5 of Series I.

Hence we may conclude from the results of the above series of photographs that exposures from $\frac{1}{3}$ to $\frac{1}{2}$ second on $\frac{f}{15}$ are sufficient to bring out satisfactorily nearly the whole of the corona shown on the photographs. The gain in extent by increasing the exposures to $1\frac{1}{2}$ seconds is not of sufficient importance to compensate for the risk of entirely losing the detail in the inner corona by over-exposure, which increases rapidly with the time.

(b) Exposures for getting the greatest extent of corona.

1. Nos. 17 and 21, Series II, exposures 2 and 4 seconds, respectively, equivalent exposures 2 seconds and 4 seconds, show a very real development of the coronal rays, probably the greatest shown on any other plate, except those obtained with the DALLMEYER in Series VI.

2. Nos. 27 and 28, Series VI, exposure 5 seconds, equivalent exposure 31 seconds, give but slight gain in extension over the preceding series, although the equivalent of exposure is $7\frac{1}{2}$ times as long.

3. Nos. 29 and 30, Series VI, exposure 20 seconds, equivalent exposure 125 seconds, were taken on triple-coated plates. These two plates carry the extension of the coronal rays very considerably farther, but the equivalent exposure is more than 30 times that of Series II, No. 21.

These are the photographs, Nos. 29 and 30, before alluded to as giving the greatest extent of the corona ever before photographed, and it is hardly possible that such success could have been achieved with any other than the triple-coated plates. We may conclude, then, that with extra rapid plates, even when heavily backed, there does not seem to be much gain by an exposure above 4 seconds for $\frac{f}{15}$. The advantage of the triple-coated plates for long exposures is strikingly shown. The exposure of VI, 29-30, is equivalent to 125 seconds $\frac{f}{15}$, yet the detail is not greatly injured by over-exposure in the brighter part, while the coronal streamers are carried farther than ever before attained. "They give a better idea of the corona as it appears to the naked eye than perhaps any other whatsoever, and in so doing they afford a strong and unexpected confirmation of the truthfulness of a large number of eclipse drawings."

(c) For plates of ordinary sensitiveness.

The plates used in this series are ordinary quick plates, not extra rapid, the exposures of which were equivalent to only $\frac{1}{4}$ to $\frac{1}{8}$ of what the extra-rapid plates in (a) and (b) would have given.

1. Series IV, Nos. 11 and 18, exposures 1 and 2 seconds, are both amply exposed.
2. Series V, Nos. 12 and 24, exposures $1\frac{1}{2}$ and 9 seconds, the second plate is very fully exposed, one of the coronal rays reaching the edge of the plate. The photograph shows great wealth of detail, yet over-exposure is beginning to show itself near the limit.
3. Series V, No. 26, exposure 30 seconds, is not equal in any respect to the second Series V above.

"It may be remarked that the two observers were well advised to use slow plates; if where there is no urgent need to cut the exposures very short, there can be no doubt that it is the wiser course to use a plate of normal sensitiveness, rather than an extra rapid, and to lengthen the exposure in proportion. The slower plate is easier to manage and safer to handle; in other words, a restrained and prolonged development can be better employed upon it, and it is less liable to accidental fog, while the grain of the deposit is usually finer. Certainly the five plates in question leave nothing to be desired as to detail and beauty."

Summing up the results, and taking $\frac{f}{a} = 15$ as a representative instrument, four classes of exposures are indicated for the most rapid plates:

1. For prominences, $\frac{1}{8}$ to $\frac{1}{4}$ of a second.
2. For the inner corona, $\frac{1}{10}$ to $\frac{1}{8}$ of a second.
3. Carrying the exposure to $\frac{1}{2}$ or $\frac{3}{4}$ of a second gives a great increase in the area commanded, and 1 second may be taken as marking almost the limit of a really useful exposure for the corona as a whole.
4. To secure the long rays, exposures of 100 seconds or upwards are necessary, sacrificing the inner corona for this purpose. It is possible that exposures of 200 or 300 seconds or even longer may be found advantageous, but exposures from 2 seconds up to 50 or 60 or upward, require the most skillful manipulation in development to render them of any service; otherwise detail in the corona proper is sacrificed without any sensible increase in the representation of the streamers. Triple-coated (non-halation) plates should be used for such long exposures, and the condition of the sky will have to be taken into consideration. If the atmospheric glare in the vicinity of the Sun be great, or if it diminish more slowly than the corona as the distance from the Sun increases, a limit will be reached beyond which the streamers can not be photographed.

"One corollary of great importance for amateur photographers results from these considerations. Where $\frac{f}{a}$ is not greater than 15, and the focal length is not greater than 5 feet, the blurring in a stationary camera of a photograph exposed for $\frac{1}{2}$ second is only $\frac{1}{100}$ inch, which is practically imperceptible. A sharp image of the whole of the main body of the corona, inner and outer, can therefore be secured by a fixed camera, and there is no need for equatorial or driving clock, heliostat, or cœlost, with the consequent expense, weight, and trouble of adjustment.

"The one and only caution to be borne in mind is that the camera should be firmly and rigidly mounted. This deduction from the results of the 1898 eclipse should lead to a large number of cameras of considerable focal length being used in the eclipse of 1900, resulting in an abundant harvest of fine photographs on a sufficient scale."

It would be a mistake to infer from this remark that such photographs would be equally valuable as those taken with the same instrument provided with a driving clock or other device for keeping the image stationary on the plate. The photograph would stand

but little enlargement, while the instrument would be cut off from the extremely interesting field of photographing the coronal streamers. It will repay considerable trouble and expense to provide some device for slow motion of the telescope or camera. An illustration has been previously given in this paper of a home-made camera provided with a simple device of this kind, by which were produced the successful photographs of Series II. A still more effective one was made by Mr. W. H. SNOWDEN, at the California Eclipse, 1889. He used an 11 x 14 camera, with a lens 3 inches aperture and 23 inches equivalent focal length, on top of which he mounted a 2-inch telescope provided with cross hairs. With this he was enabled to make two successful exposures of 28 and 41 seconds, respectively.

The choice of instruments is not limited to cameras and photographic telescopes. Professor BARNARD's beautiful photograph of the corona of the 1889 California Eclipse shows that a visual objective, with the aperture sufficiently reduced, may give excellent results. He used a $3\frac{1}{2}$ -inch CLARK equatorial, 49 inches focal length, with the aperture reduced to $1\frac{3}{4}$ inches. With an exposure of $4\frac{1}{2}$ seconds on a moderately rapid plate, he obtained as large an extent of the corona and as great wealth of detail as Professor PICKERING with his 13-inch photographic telescope of 196 inches focal length, the latter using a slow plate.

In focusing the instrument, it should be pointed at a well-defined object, distant, say from a quarter-mile to a mile, and the object brought to a sharp focus for the center of the plate. The image of the eclipsed Sun is really a small object, and occupies but a comparatively small part of the center of the field. The focal length of the camera in inches will give roughly the diameter of the Sun's image in *hundredths of an inch*. The image of the corona will be from 2 to 4 times these dimensions.

To secure the best results, however, it would be better to determine the stellar focus by photographing trails of stars, and selecting the adjustment which gives the sharpest definition (finest line) in the center of the field. In this connection, it is important to notice that Professor BARNARD's success with the visual telescope, noted above, was made possible by the great care with which he thus determined the photographic focus of his instrument.

One precaution must be rigidly observed—the original negative must not be retouched or altered, as it will destroy entirely its scientific value.

The U. S. Naval Observatory will publish an extensive report on the eclipse results, and would be glad to include photographs which may possess sufficient scientific merit. If the original negative is sent to the Observatory, it will be returned after using. The data accompanying such negatives should include a description of the apparatus, kind of plate and developer, length of exposure, and location of station. The plate should also have been marked previous to exposure, to indicate the top side of the plate.

IV.—TELESCOPIC OBSERVATIONS.

Telescopes.—A proper telescope for observing the eclipse is very desirable, but any telescope at all is better than none; and owners of small spy-glasses, or opera-glasses, should bear in mind that their instruments are capable of doing good service. Opera-glasses can be held in the hand with sufficient steadiness, but spy-glasses, however small, will require a stand to produce the best effect. This need not be an elaborate affair, but may be made of wood in the simplest manner, provided only that it is capable of holding the telescope steadily pointed in any required direction. Some artificial support is necessary, and, in default of anything better, the telescope might even be lashed to a round post.

Shade glasses.—For the first and last contact shade glasses will be necessary. The best form is undoubtedly a long wedge of colored glass, achromatized by a similar wedge of white glass firmly cemented to it. The most usual, and by far the most objectionable, color for a shade is red. Either a neutral tint or green is excellent, but it is difficult to

obtain the latter sufficiently dark, while deep blue has been advocated by some observers. Shades consisting of a single piece of thick glass are very apt to split, and thus endanger the observer's eye, if the rays of a bright sun are concentrated upon them by an objective of large aperture. To avoid this, such objectives must have their aperture reduced by a cap to about one-half the usual size. By making the shade of three thicknesses of glass, the piece next the eye being thickest and darkest in color, the other pieces being successively thinner and lighter in color, and all being fitted loosely into their cell so that they can expand freely, it will be possible to use with safety an aperture of 5 inches upon a telescope of 6 feet focus. When no proper shade is at hand, an excellent substitute can be made by smoking a slip of thin flat glass, about an inch wide and 4 inches long, in such a way that its tint may increase uniformly, from very light at one end to a depth at the other end sufficient for viewing the brightest Sun without inconvenience. The smoked surface should be protected by a covering glass, of the same size as the original slip, and separated from it by bits of thin card inserted at the ends, the whole being bound together by a narrow strip of paper pasted around the edges. For observing the second contact of the eclipse, a neutral tint, or green, spectacle glass will be found convenient.

Of course it will be understood that the necessity for caps to diminish the aperture is confined to common telescopes. Instruments intended for observing the Sun are always provided with arrangements for getting rid of the excessive light and heat without diminishing the aperture, and often without using shades.

Heating of telescope.—When observing a bright Sun the eye end of the telescope soon becomes quite hot, and thus air currents are set up in the tube which interfere seriously with the definition. To remedy this the tube must occasionally be cooled, either by shading the objective or by turning the telescope away from the Sun. As it is important to have the best possible definition while observing the contacts and totality of the eclipse, special care must be taken that the temperature of the tube at these times is the same as that of the surrounding air.

First contact.—There is generally some uncertainty about the first contact, because the only evidence of its occurrence is a slight indentation in the Sun's limb, which, unless the observer knows precisely where to look for it, naturally attains some size before it is seen, and thus the contact is noted too late. If the telescope has a position-micrometer, its wire may be set at the computed point of first contact, and then there will be no difficulty; but in the absence of such an arrangement, the only way is to use a power of not more than sixty diameters, and to watch carefully a portion of the Sun's circumference large enough to include with certainty the point in question. The shade glass employed should be sufficiently dark to destroy all glare, and to permit of the Sun's image being viewed without effort.

Second contact.—The internal contacts, or beginning and end of totality, are phenomena of such a definite character that the instants of their occurrence can be noted within a small fraction of a second. For a minute or two before the predicted time of second contact the Sun's thin, and now fast waning, crescent should be carefully watched through a neutral tint or green shade glass as light as the eye can conveniently bear. Presently the crescent will become a mere thread of light, which will rapidly shorten and suddenly disappear. This is the second contact, and there can be no mistake about the exact instant of its occurrence, because the ruddy glow of the chromosphere, which remains at the point last covered by the Moon, is totally different from the dazzling white light of the photosphere which has just disappeared. Through a red shade glass the contrast between these two kinds of light might be partly lost, but through a neutral tint or green glass it will be sufficiently apparent. Finally, there is yet another indication of the second con-

and that is the seemingly miraculous appearance of the complete outline of the Moon, and black, reposing upon the wondrous radiance of the coróna.

Third contact.—The approach of the third contact will be heralded by the rapid darkening of the chromosphere at the point of the Moon's limb where the Sun is about to appear, and two or three seconds later a sudden burst of light will announce the contact itself and with it the termination of totality. This contact may be observed without shade glass.

Fourth contact.—The observation of the fourth contact is a very simple matter. The segment cut out of the Sun by the retreating limb of the Moon is carefully watched as it becomes less and less, and the instant of its final disappearance is noted as the fourth contact. The shade glass used must be so dark as to destroy all disagreeable glare.

The party to observe the contacts should consist of two persons, one of whom should have a timepiece and writing materials and the other a telescope. With regard to the latter instrument, it may be remarked that if it is a common one—a spyglass, for instance—there will probably be no choice as to its magnifying power; but if it belongs to the better class, and has a battery of eyepieces, the power chosen should be equal to fifteen or twenty times the diameter of the objective in inches. To secure the best results the party should be entirely alone, above all, not within hearing of other observing parties. A minute or so before the expected time of contact the person with the timepiece will fix his eyes upon its second hand and begin silently to count the seconds, while the observer with the telescope will carefully watch the Sun. Upon the occurrence of contact the observer will cry "Mark," and the person at the timepiece will immediately write down, first, the second; then, the minute; and, finally, the hour. Before beginning to observe, care must be taken to see that when the second hand points to 60, the minute hand is exactly over a minute mark; and in observing, if the seconds are near sixty, special care will be required to avoid recording a wrong minute. Practice in calling and noting time previous to the eclipse will greatly diminish the risk of such mistakes. A little before totality a lantern should be lighted, because without it there may be difficulty in seeing the hands of the timepiece at the approach of third contact.

Chronometer or timepiece.—Observations of the internal contacts can be utilized without a knowledge of the error of the timepiece; but with the external contacts the case is different. They will be of no value unless the error of the timepiece is accurately known, either on local or on Washington time. To meet this difficulty, it is hoped that arrangements may be made by which the Western Union Telegraph Company will furnish, free of cost, a signal from the Naval Observatory, indicating the instant of Washington mean noon, to all proper persons who may apply for it at any of their offices on May 26, 28, and 29. The intending observer can best utilize these signals by making sure that the minute and second hands of his watch agree with each other, as explained above, and then carrying the watch to the telegraph office on each of the days mentioned and noting the hour, minute, and second indicated by it when the signal is received. No matter how the watch may run, it must not be meddled with in any way, either by moving its hands or touching its regulator, between May 26 and 29. Without this precaution, neither its rate, nor the degree of dependence to be placed upon it, can be determined.

The final record of a set of observations of contacts should contain the following information:

1. The name of the station; including town, county, and State.
2. The date.
3. A description of the location of the station with reference to the nearest prominent landmarks, as, for example, its bearing and distance from the nearest court-house, railroad

station, or church; or its position with respect to the lines of the United States land surveys; or the bearing and distance of a prominent mountain peak; or the bearings of three or more such mountain peaks; or, in the case of a city, the street and number, together with the names of the nearest cross streets on each side.

4. A description of the timepiece, and a statement of the aperture, focal length, and magnifying power of the telescope employed.

5. The times indicated by the watch at the reception of the Washington noon signal on May 26, 28, and 29.

6. The time of each of the contacts, just as read from the face of the watch, without the application of any correction.

7. An estimate of the uncertainty to which these times are liable.

8. Any remarks which may be thought necessary.

9. The signatures of the two observers, thus: A. B., observer with telescope; C. D., time observer.

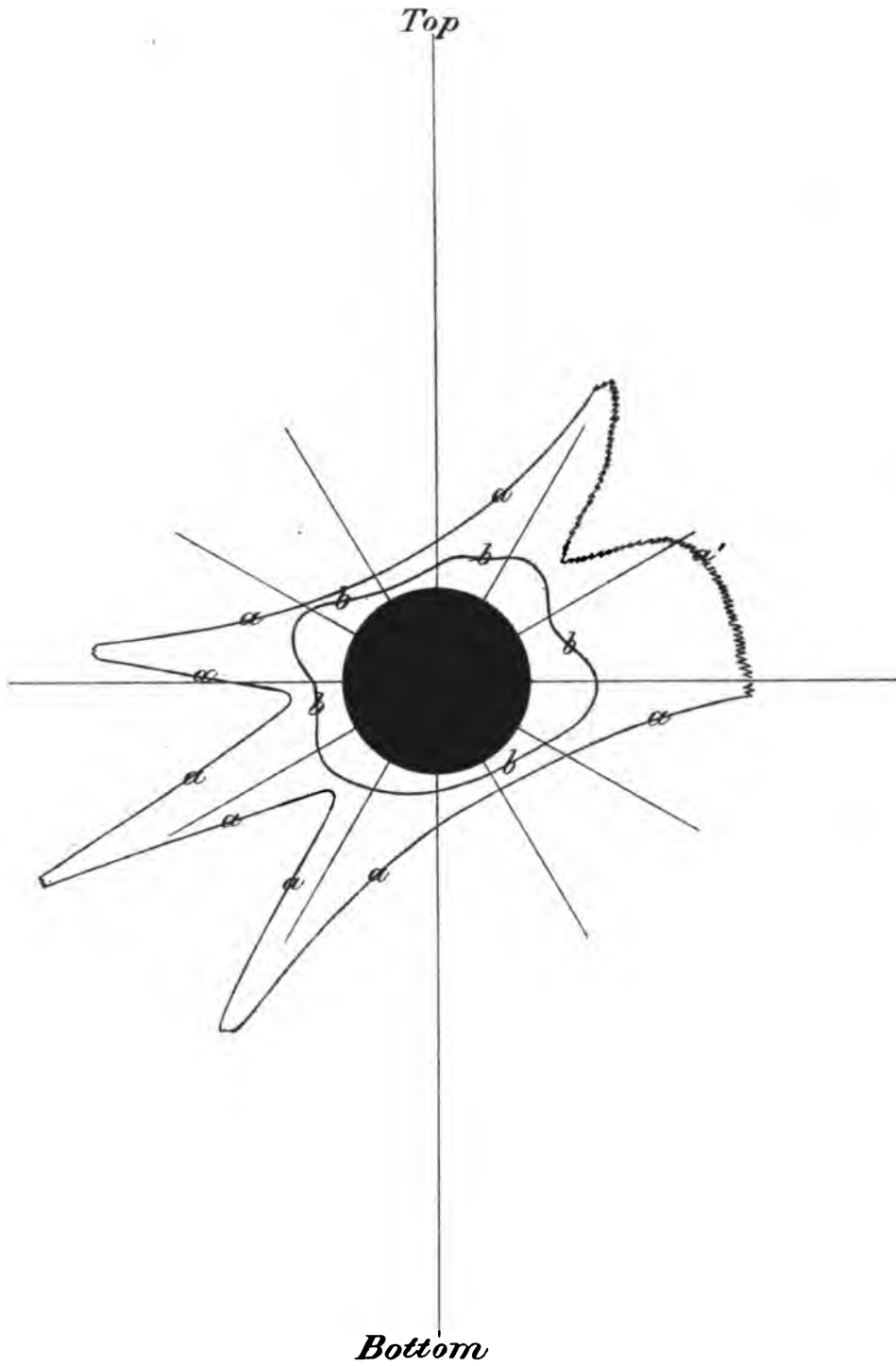
It is particularly requested that the original pencil memoranda of the times of contact be sent to the Naval Observatory, inclosed in the above-described report.

If several parties observe the eclipse in the same neighborhood, it is quite likely that their recorded times may differ a little. Such differences occur even in the work of the most practiced astronomers; and they must be allowed to remain. It is never permissible to alter the record. A mere suspicion that such a thing has been done will insure the entire rejection of the observation.

Limits of the shadow path.—There is yet much uncertainty in the best lunar tables. It is therefore important to determine accurately the true position of the path, and this may be readily accomplished by observing the duration of totality at points situated from 1 to 10 miles within the shadow. As the duration of totality is the interval between the second and third contacts, it is determined by observing these contacts in the manner already described, except that for this purpose a knowledge of the error of the watch is unnecessary, and the observations may be made with the naked eye if a telescope is not available. At places very near the edge of the shadow the totality may be so brief that the time observer would risk losing the third contact if he stopped to record the second. At such places it will be necessary to have a third person to make the record, and then both contacts can be readily observed, even if they follow each other at an interval as short as a single second.

Since these valuable observations are so easily made it is hoped that advantage will be taken of the opportunity by many who may reside or may find themselves within the path of totality. Great care should be taken to record as accurately as possible the instant of beginning and ending of totality as described in the preceding paragraphs under the head of second and third contacts.

Plate I.





PART II.

ASTRONOMICAL DATA AND CHARTS.

TOTAL ECLIPSE OF THE SUN, MAY 28, 1900.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of δ in right ascension, May 28 02 57 02.7				
Sun and Moon's R. A.	^h 4 ^m 19 ^s 47.38	Hourly motions	^s 10.16 and ^s 149.08	
Sun's declination	21 27 16.0 N.	Hourly motion	0 24.2 N.	
Moon's declination	21 50 17.4 N.	Hourly motion	2 41.0 N.	
Sun's equa. hor. parallax	8.7	Sun's true semidiameter	15 46.6	
Moon's equa. hor. parallax	58 27.4	Moon's true semidiameter	15 55.0	

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time.	Longitude from Greenwich.	Latitude.
	^d ^h ^m	[°] ' "	[°] ' "
Eclipse begins	May 28 00 12.5	97 49.5 W.	9 59.2 N.
Central eclipse begins	28 01 14.5	116 38.4 W.	17 50.3 N.
Central eclipse at noon	28 02 57.0	45 00.4 W.	44 56.8 N.
Central eclipse ends	28 04 33.5	31 37.1 E.	25 20.6 N.
Eclipse ends	28 05 35.6	12 29.4 E.	17 32.8 N.

This eclipse will commence in the Pacific Ocean, and as a partial eclipse will spread over the whole of North America, part of South America, the whole of Europe, some portions of Asia, and the northern part of Africa. The total phase will also commence in the Pacific Ocean, cross Mexico and the United States, as shown on Charts III and IV; it will then pass over to Spain, skirt the northern coast of Africa, and end just before reaching the Red Sea.

TOTAL ECLIPSE OF THE SUN, MAY 28, 1900.

The present pamphlet has been prepared chiefly from the tables and data given in the American Ephemeris for 1900, and is intended for the use of observers stationed along the line of totality between Mexico and the Atlantic Ocean. Four maps or charts are appended: (I) Giving a general outline of the entire eclipse; (II) giving the planets and stars in the vicinity of the eclipsed Sun; (III) giving the Path of Total Eclipse from the Pacific Ocean to the Gulf of Mexico; and (IV) showing the portion of this path from Louisiana to the Atlantic Ocean.

In Charts III and IV the shadow path is crossed at more or less uniform intervals by straight dotted lines which terminate in the north and south limits of totality. Each of these lines is approximately the locus of all points for which the *Middle of Total Eclipse* occurs at the moment of Greenwich mean time indicated thereon. Over the region included by Chart III the motion of the shadow is so rapid that these dotted lines are given at intervals of one minute of mean time; while in Chart IV the adopted interval is five minutes. The time of *Middle of Total Eclipse* at any point whose position is plotted on either chart can therefore be determined quite accurately by mere inspection.

Chart IV contains, further, a series of long curved dotted lines, each of which includes all points for which either the beginning or ending of partial eclipse will occur at the moment indicated. From the position of any station relatively to these lines, the Greenwich mean times of the first and last contacts at that station may be very approximately determined. The method of computing *accurate* times of the several phases from the Besselian Elements will be explained further on.

The general *Elements of the Eclipse* are given for the moment of conjunction of the Sun and Moon in right ascension; but the subsequent tables and results are computed from the exact positions of these bodies at the several instants referred to. The principal *Circumstances of the Eclipse* are defined as follows:

On the line "Eclipse begins" is given the Greenwich mean time at which the Moon's penumbra first touches the Earth, together with the latitude and longitude of the point of contact.

On the line "Central eclipse begins" is given the time when the axis of the Moon's shadow first touches the Earth, and the latitude and longitude of the point of contact follow.

On the line "Central eclipse at noon" is given the time when the axes of the Earth and of the shadow cone lie in the same plane. The latitude and longitude of the point where the axis of the shadow cone then cuts the Earth's surface follow, and there the eclipse will be central and the Sun will be exactly on the meridian.

The phrases "Central eclipse ends" and "Eclipse ends" are followed by a statement of the times when, and the localities where these events occur; the phenomena being the converse of those denoted by the similar phrases for the beginning.

TABLES.

Table I contains the Besselian Elements, or the data from which accurate times of the phases may be computed for any station whose co-ordinates are known.

Table II gives the latitude and longitude of points along the central line, and also of corresponding points on the northern and southern limits of the shadow path, for which

the middle of totality occurs at the moment indicated in the first column. The final column gives the duration of totality at the points on the central line.

Table III is a special table prepared for the convenience of local observers in the United States. The two parts of this table have reference to the beginning and ending of partial eclipse, respectively, and contain the following data:

Columns three and four give the latitudes and longitudes of certain points (indicated by dots on the beginning and ending curves of Chart III) where the eclipse is either beginning or ending at the time designated both upon the corresponding chart curves and in column one of the table.

Column two gives the local mean time (in civil reckoning) of beginning or ending of partial eclipse at the points in question.

The fifth and final column gives the position-angle P (reckoned from the north point of the Sun's disk toward the east) of the point of contact for the stations indicated.

RIGOROUS COMPUTATION OF THE TIMES.

An accurate determination of the several phases, as visible at any particular station, may be obtained from the *Besselian Elements*, which are given in Table I for every ten minutes of Greenwich mean time. Their geometric signification is as follows:

Let us imagine a plane passing through the center of the Earth, perpendicular to the right line joining the centers of the Sun and Moon. This latter line is the axis of the Moon's shadow, and the plane is called the *fundamental plane* or plane of xy . We take the intersection of this plane with that of the Earth's equator as the axis of x , and the center of the Earth as the origin of co-ordinates. The axis of y is perpendicular to that of x , and directed toward the north; x and y are then the co-ordinates of the point in which the axis of the shadow intersects the fundamental plane, and they are here expressed in terms of the Earth's equatorial radius as unity. The angle d , of which the sine and cosine are both given, is the declination of that point of the celestial sphere toward which the axis of the shadow is directed; or, in other words, it is the declination of the center of the Sun as seen from the center of the Moon. The angle μ is the Greenwich hour-angle of this same point of the celestial sphere.

The quantities l_1 and l_2 are the radii of the shadow-cones upon the fundamental plane, l_1 corresponding to the penumbra, and l_2 to the umbra or shadow. The angles f_1 and f_2 , the tangents of which are given, are the angles which the elements of the respective shadow-cones make with the axis of the shadow, or they are the semi-angles of the two cones. The values of x' , y' , and μ' , which are the changes of x , y , and μ , in one minute of mean time, are also given at the bottom of the table.

The method of computing an eclipse from its Besselian Elements is based on the fact that at the moments of beginning and ending the distance of the observer from the axis of the shadow or penumbra is equal to the radius of the latter at the point of observation. To find this distance and radius we proceed as follows:

(1) The co-ordinates of the observer, ξ , η , and ζ , together with their variations in one minute, are computed for some assumed moment of Greenwich mean time, as near as practicable to the true time of the required phase.

(2) The co-ordinates x and y of the axis of the shadow, together with their variations in one minute, are taken for the same moment from the tables of elements.

(3) From (1) and (2) the position and motion of the observer relative to the axis of the shadow are found.

(4) The radius of the penumbra or umbra at a distance from the fundamental plane equal to that of the observer is also computed.

(5) Then, assuming the motions to be uniform, we determine the time required for the observer to be brought to a distance from the axis of the shadow equal to this radius.

The formulæ and directions for the several steps in the computation are as follows:

(1) Find $\rho \cos \varphi'$ and $\rho \sin \varphi'$, which are the geocentric co-ordinates of the station referred to the Earth's equator, ρ being the distance from the center of the Earth, and φ' the geocentric latitude. These co-ordinates may be obtained from geodetic tables, or may be computed from the following table based on CLARKE'S spheroid of 1866, by the formulæ—

$$\rho \cos \varphi' = F \cos \varphi$$

$$\rho \sin \varphi' = \frac{\sin \varphi}{G}$$

φ being, as usual, the geographic latitude.

Table for Computing the Geocentric Co-ordinates of a Place.

φ	Log F.	Log G.
0°	0.00000	0.00295
5	0.00001	0.00294
10	0.00004	0.00291
15	0.00010	0.00285
20	0.00017	0.00278
25	0.00026	0.00269
30	0.00037	0.00258
35	0.00048	0.00247
40	0.00061	0.00234
45	0.00074	0.00221
50	0.00086	0.00209
55	0.00099	0.00196
60	0.00111	0.00184
65	0.00121	0.00174
70	0.00130	0.00165
75	0.00138	0.00157
80	0.00143	0.00152
85	0.00146	0.00149
90	0.00147	0.00147

For the assumed Greenwich mean time of computation, take from Table I the values of $\sin d$, $\cos d$, and μ . Then with λ for the longitude west from Greenwich, the co-ordinates of the observer will be—

$$\xi = \rho \cos \varphi' \sin (\mu - \lambda)$$

$$\eta = \rho \sin \varphi' \cos d - \rho \cos \varphi' \sin d \cos (\mu - \lambda) = \eta_1 - \eta_2$$

$$\zeta = \rho \sin \varphi' \sin d + \rho \cos \varphi' \cos d \cos (\mu - \lambda) = \zeta_1 + \zeta_2$$

and their variations in one minute of mean time will be—

$$\xi' = [7.63992] \rho \cos \varphi' \cos (\mu - \lambda)$$

$$\eta' = [7.63992] \rho \cos \varphi' \sin d \sin (\mu - \lambda) = [7.63992] \xi \sin d$$

$$\zeta' \text{ is not needed.}$$

(2) For the same assumed moment of Greenwich mean time, take from Table I the co-ordinates x and y of the axis of the shadow, together with their variations for one minute. These variations are represented by x' and y' , and their values are given at the foot of the table.

(3) The distance m and position-angle M of the axis of the shadow relative to the observer, and the relative motions, n and N , are computed by the formulæ—

$$m \sin M = x - \xi$$

$$m \cos M = y - \eta$$

$$n \sin N = x' - \xi'$$

$$n \cos N = y' - \eta'$$

(4) Both for the shadow and for the penumbra, the radius L at the distance ζ from the fundamental plane is computed by the formula,

$$L = l - \zeta \tan f$$

l and f being found in Table I, and ζ computed in (1).

(5) If the time chosen for computation is exactly that of the beginning or ending of the eclipse, we shall have

$$m = L$$

But, as this condition will rarely be fulfilled on a first trial, a correction τ to the assumed time is computed thus: Find the angle ψ from the equation,

$$\sin \psi = \frac{m \sin (M - N)}{L}$$

There will be two values for this angle, of which one will be in the first and the other in the second quadrant when $\sin \psi$ is positive, and one in the third and the other in the fourth quadrant when $\sin \psi$ is negative. The correction τ to the assumed time of beginning or ending of the eclipse will then be found, in minutes, from—

$$\tau = - \frac{m \cos (M - N)}{n} + \frac{L \cos \psi}{n} \quad (a)$$

In order to attain the required accuracy without the necessity of a second approximation, we commence the computation by assuming three times, namely: one near the beginning of the partial eclipse; a second, near the middle of totality; and a third, near the ending of partial eclipse. These times can easily be taken from the charts to the nearest minute of Greenwich mean time, in the manner already explained. We shall designate these approximate times t_1 , t_2 , and t_3 , respectively. Then, for the time t_1 , compute from (a) the value of τ which results when $\cos \psi$ is taken negative and the penumbral value of L is employed. Let τ_1 designate this quantity. Again taking the penumbral value of L , compute for the time t_3 the value of τ given by (a) when $\cos \psi$ is positive—denoting this value by τ_3 . These computations determine the beginning and ending of partial eclipse.

To find the exact times of beginning and ending of totality, compute for the moment t_2 the two values of τ given by (a) when $\cos \psi$ is taken with the double sign, and L is computed for the shadow. Designating by τ_2 and τ_2' the pair of values thus found, corresponding to the positive and negative cosines, respectively, we shall have, for the accurate times of the four phases—

I. Eclipse begins	T_1	$=$	$t_1 + \tau_1$	}	Greenwich Mean Time.
II. Totality begins	T_2	$=$	$t_2 + \tau_2$		
III. Totality ends	T_3	$=$	$t_2 + \tau_2'$		
IV. Eclipse ends	T_4	$=$	$t_3 + \tau_3$		

These times are at once reduced to local mean time by applying the observer's longitude.

The position-angle P , of the point of contact, reckoned from the north point of the Sun's limb toward the east, is found by the formula—

$$P = N + \psi$$

it being assumed that the values of N and ψ are taken from the computation of the phase for which P is required.

The angle from the vertex, V , also reckoned toward the east, is given by the formula

$$V = P - C$$

where C is computed from the expression

$$\tan C = \frac{\xi + \tau \xi'}{\eta + \tau \eta'}$$

and $\sin C$ has the sign of $\xi + \tau \xi'$. The values of ξ , η , ξ' , η' , and τ employed in the latter formula must be taken from the computation of the phase for which V is required.

As an example of the foregoing precepts, we append a detailed computation of the Total Solar Eclipse of 1900, May 28, for Norfolk, whose position is—

$$\begin{aligned} \text{Latitude, } \varphi &= + 36^{\circ} 49' 33'' \\ \text{Longitude, } \lambda &= + 76^{\circ} 17' 46'' \end{aligned}$$

Constants for the given place—

$$\rho \sin \varphi' = 9.77529$$

$$\rho \cos \varphi' = 9.90387$$

From Chart IV we find the approximate times of the phases to be—

			d	h	m	
Beginning of eclipse,	$t_1 =$	May	28	00	41	} Greenwich Mean Time.
Middle of totality,	$t_2 =$		28	01	53	
Ending of eclipse,	$t_3 =$		28	03	15	

The computation for these assumed times is as follows:

Greenwich Mean Time,	May	Beginning. 28 ^d 00 ^h 41 ^m	Total Phase. 1 ^h 53 ^m	Ending. 3 ^h 15 ^m
		° ' "	° ' "	° ' "
μ		10 59 36	28 59 42	49 29 42
λ		76 17 46	76 17 46	76 17 46
$\mu - \lambda$		294 41 50	312 41 56	333 11 56
$\rho \cos \varphi'$		9.90387	9.90387	9.90387
$\sin (\mu - \lambda)$		— 9.95834	— 9.86625	— 9.65408
$\log \xi$		— 9.86221	— 9.77012	— 9.55795
ξ		— 0.72813	— 0.58900	— 0.36137
$\rho \sin \varphi'$		9.77529	9.77529	9.77529
$\cos d$		9.96886	9.96884	9.96881
$\log \eta_1$		9.74415	9.74413	9.74410
η_1		+ 0.55481	+ 0.55479	+ 0.55475
$\rho \cos \varphi'$		9.90387	9.90387	9.90387
$\sin d$		9.56289	9.56305	9.56322
$\cos (\mu - \lambda)$		9.62099	9.83132	9.95065
$\log \eta_2$		9.08775	9.29824	9.41774
η_2		+ 0.12239	+ 0.19872	+ 0.26166
$\eta_1 - \eta_2$		+ 0.43242	+ 0.35607	+ 0.29309
$\rho \sin \varphi' \sin d$		9.33818	9.33834	9.33851
η_1		+ 0.21786	+ 0.21794	+ 0.21802
$\rho \cos \varphi' \cos d \cos (\mu - \lambda)$		9.49372	9.70403	9.82333
η_2		+ 0.31169	+ 0.50586	+ 0.66578
$\zeta_1 + \zeta_2$		+ 0.54955	+ 0.72380	+ 0.88380
const. log		7.63992	7.63992	7.63992
$\rho \cos \varphi' \cos (\mu - \lambda)$		9.52486	9.73519	9.85452
$\log \xi'$		7.16478	7.37511	7.49444

Greenwich Mean Time,	May	Beginning. 28 ^d 00 ^h 41 ^m	Total Phase. 1 ^h 53 ^m	Ending. 3 ^h 15 ^m
	ξ'	+ 0.001461	+ 0.002372	+ 0.003122
	const. log	7.63992	7.63992	7.63992
	$\xi \sin d$	- 9.42510	- 9.33317	- 9.12117
	log η'	- 7.06502	- 6.97309	- 6.76109
	η'	- 0.001162	- 0.000940	- 0.000577
	$x - \xi$	- 0.52542	- 0.00116	+ 0.52681
	$y - \eta$	- 0.12746	- 0.00333	+ 0.11350
	$x' - \xi'$	+ 0.007752	+ 0.006842	+ 0.006093
	$y' - \eta'$	+ 0.001830	+ 0.001601	+ 0.001230
	$m \sin M$	- 9.72051	- 7.06446	9.72166
	$m \cos M$	- 9.10537	- 7.52244	9.05500
	tan M	0.61514	9.54202	0.66666
	M	256° 21' 52"	199° 12' 22"	77° 50' 30"
	sin M	- 9.98759	- 9.51715	9.99014
	log m	9.73292	7.54731	9.73152
	$n \sin N$	7.88941	7.83518	7.78483
	$n \cos N$	7.26245	7.20439	7.08991
	tan N	0.62696	0.63079	0.69492
	N	76° 43' 02"	76° 49' 47"	78° 35' 13"
	sin N	9.98822	9.98842	9.99133
	log n	7.90119	7.84676	7.79350
	tan f	7.66390	7.66174	7.66390
	log ζ	9.72391	9.85962	9.94635
		7.38781	7.52136	7.61025
	$\zeta \tan f$	+ 0.00244	+ 0.00332	+ 0.00408
	l	+ 0.54319	- 0.00252	+ 0.54355
	L	+ 0.54075	- 0.00584	+ 0.53947
	$M - N$	179° 38' 50"	122° 22' 35"	359° 15' 17"
	sin ($M - N$)	7.78938	9.92662	- 8.11418
	log m	9.73292	7.54731	9.73152
	colog L	0.26700	- 2.23359	0.26803
	sin ψ	7.78930	- 9.70752	- 8.11373
	ψ	179° 38' 50"	329° 20' 25" 210 39 35	359° 15' 20"
	log $\frac{m}{n}$	1.83173	9.70055	1.93802
	cos ($M - N$)	- 9.99999	- 9.72875	9.99996
		- 1.83172	- 9.42930	1.93798
	$-\frac{m}{n} \cos (M - N)$	+ 67.877	+ 0.269	- 86.692
	log J	9.73300	- 7.76641	9.73197
	cos ψ	- 9.99999	± 9.93460	9.99996
	colog n	2.09881	2.15324	2.20650
		- 1.83180	± 9.85425	1.93843

Greenwich Mean Time,	May	Beginning. 28 ^d 00 ^h 41 ^m	Total Phase. 1 ^h 53 ^m	Ending. 3 ^h 15 ^m
	$+ \frac{L \cos \phi}{n}$	- 67.889	∓ 0.715	+ 86.782
	τ	- 0.012	$+ 0.984$	+ 0.090
	t	0 41	1 53	3 15
	$t + \tau$	0 40.988	1 52.554 1 53.984	3 15.090
	λ	+ 5 05.184	+ 5 05.184	+ 5 05.184
Local Astronomical Mean Time,	May 27 19 35.804	27 20 47.370 27 20 48.800	27 22 09.906	
Local Civil Mean Time, A. M.,	May 28 07 35.804	28 08 47.370 28 08 48.800	28 10 09.906	
Duration of totality,		1.430		

Finally, the computation of the position angles P and V for the beginning and ending of partial eclipse is as follows:

To find P :

	Beginning.	Ending.
N	76 43.0	78 35.2
ϕ	179 38.8	359 15.3
Position angle P	256 21.8	77 50.5

from the north point of the Sun's disk toward the east for direct image.

To find V :

	Beginning.	Ending.
$\log \xi'$	7.16478	7.49444
$\log \tau$	- 8.07918	8.95424
$\log \eta'$	- 7.06502	- 6.76109
$\log \tau \xi'$	- 5.24396	6.44868
$\log \tau \eta'$	5.14420	- 5.71533
ξ	- 0.72813	- 0.36137
$\tau \xi'$	- 0.00002	+ 0.00028
$\xi + \tau \xi'$	- 0.72815	- 0.36109
η	+ 0.43242	+ 0.29309
$\tau \eta'$	+ 0.00001	- 0.00005
$\eta + \tau \eta'$	+ 0.43243	+ 0.29304
$\log (\xi + \tau \xi')$	- 9.86222	- 9.55762
$\log (\eta + \tau \eta')$	9.63592	9.46693
$\log \tan C$	- 0.22630	- 0.09069
C	300 42.3	309 03.7
P	256 21.8	77 50.5
Position angle V	315 39.5	128 46.8

from the vertex of the Sun's disk toward the east for direct image.

TABLE I.—BESSELIAN ELEMENTS OF THE TOTAL ECLIPSE
OF THE SUN, 1900, MAY 28.

Greenwich Mean Time.	Co-ordinates of Center of Shadow on Fundamental Plane.		Direction of Axis of Shadow.			Radius of Penumbra and Shadow on Fundamental Plane.	
	x	y	Log sin d	Log cos d	μ	l_1	l_2
h m					° '		
0 0	-1.631 25	+0.277 52	+9.562 80	+9.968 88	0 44.6	+0.543 08	-0.002 82
10	1.539 13	0.284 23	9.562 82	9.968 87	3 14.6	0.543 11	0.002 79
20	1.447 01	0.290 92	9.562 84	9.968 87	5 44.6	0.543 14	0.002 76
30	1.354 89	0.297 61	9.562 87	9.968 87	8 14.6	0.543 16	0.002 73
40	1.262 76	0.304 29	9.562 89	9.968 86	10 44.6	0.543 19	0.002 70
50	1.170 63	0.310 95	9.562 91	9.968 86	13 14.7	0.543 22	0.002 68
1 0	-1.078 49	+0.317 61	+9.562 93	+9.968 86	15 44.7	+0.543 25	-0.002 65
10	0.986 36	0.324 26	9.562 95	9.968 85	18 14.7	0.543 28	0.002 63
20	0.894 22	0.330 90	9.562 97	9.968 85	20 44.7	0.543 30	0.002 60
30	0.802 08	0.337 53	9.562 99	9.968 85	23 14.7	0.543 32	0.002 58
40	0.709 94	0.344 15	9.563 02	9.968 84	25 44.7	0.543 34	0.002 55
50	0.617 80	0.350 76	9.563 04	9.968 84	28 14.7	0.543 37	0.002 53
2 0	-0.525 65	+0.357 37	+9.563 06	+9.968 84	30 44.7	+0.543 39	-0.002 50
10	0.433 51	0.363 96	9.563 08	9.968 83	33 14.7	0.543 41	0.002 48
20	0.341 36	0.370 54	9.563 10	9.968 83	35 44.7	0.543 44	0.002 46
30	0.249 22	0.377 12	9.963 12	9.968 83	38 14.7	0.543 46	0.002 43
40	0.157 07	0.383 68	9.563 14	9.968 82	40 44.7	0.543 48	0.002 41
50	-0.064 92	0.390 24	9.563 17	9.968 82	43 14.7	0.543 50	0.002 39
3 0	+0.027 22	+0.396 78	+9.563 19	+9.968 82	45 44.7	+0.543 52	-0.002 37
10	0.119 37	0.403 32	9.563 21	9.968 81	48 14.7	0.543 54	0.002 36
20	0.211 51	0.409 85	9.563 23	9.968 81	50 44.7	0.543 56	0.002 34
30	0.303 66	0.416 37	9.563 25	9.968 81	53 14.7	0.543 57	0.002 32
40	0.395 80	0.422 87	9.563 27	9.968 80	55 44.7	0.543 59	0.002 31
50	0.487 94	0.429 37	9.563 29	9.968 80	58 14.7	0.543 61	0.002 29
4 0	+0.580 08	+0.435 86	+9.563 31	+9.968 80	60 44.7	+0.543 62	-0.002 28
10	0.672 22	0.442 34	9.563 34	9.968 79	63 14.7	0.543 64	0.002 26
20	0.764 36	0.448 81	9.563 36	9.968 79	65 44.7	0.543 65	0.002 25
30	0.856 50	0.455 27	9.563 38	9.968 79	68 14.7	0.543 66	0.002 24
40	0.948 63	0.461 72	9.563 40	9.968 78	70 44.7	0.543 67	0.002 22
50	1.040 76	0.468 17	9.563 42	9.968 78	73 14.7	0.543 68	0.002 21
5 0	+1.132 88	+0.474 60	+9.563 44	+9.968 78	75 44.7	+0.543 69	-0.002 20
10	1.225 01	0.481 02	9.563 46	9.968 77	78 14.7	0.543 70	0.002 19
20	1.317 13	0.487 43	9.563 48	9.968 77	80 44.7	0.543 71	0.002 18
30	1.409 25	0.493 84	9.563 51	9.968 77	83 14.7	0.543 72	0.002 17
40	+1.501 36	+0.500 23	+9.563 53	+9.968 76	85 44.7	+0.543 73	-0.002 16

Greenwich Mean Time.	x'	y'	μ'	Log tan f_1 (Penumbra.)	Log tan f_2 (Shadow.)
h m			° '		
0 0	+ 0.009 212	+ 0.000 672	+ 0 15.0	+7.663 91	+7.661 74
1 0	0.009 213	0.000 666	0 15.0	7.663 90	7.661 74
2 0	0.009 214	0.000 660	0 15.0	7.663 90	7.661 74
3 0	0.009 215	0.000 654	0 15.0	7.663 90	7.661 73
4 0	0.009 214	0.000 648	0 15.0	7.663 90	7.661 73
5 0	+ 0.009 213	+ 0.000 643	+ 0 15.0	+7.663 89	+7.661 73

TABLE II.—PATH OF THE SHADOW DURING THE TOTAL ECLIPSE OF THE SUN, 1900, MAY 28.

Greenwich Mean Time.	Northern Limit of Shadow Path.		Central Line.		Southern Limit of Shadow Path.		Duration of Totality on Central Line.
	Latitude.	Longitude from Greenwich.	Latitude.	Longitude from Greenwich.	Latitude.	Longitude from Greenwich.	
Limits.	° ' "	° ' "	° ' "	° ' "	° ' "	° ' "	m s
1 ^h 15 ^m	+ 17 59.3	116 44.3 W.	+ 17 50.3	116 38.4 W.	+ 17 40.2	116 30.7 W.	
20	19 33.3	112 58.4	19 50.3	111 46.7	20 02.6	110 45.6	0 37.7
25	24 54.2	101 14.8	24 50.4	100 44.3	24 46.6	100 13.8	0 54.4
	27 44.2	95 28.7	27 36.8	95 01.7	27 29.4	94 34.7	1 04.4
30	+ 29 56.3	91 05.1	+ 29 46.5	90 39.7	+ 29 36.7	90 14.3	1 12.6
35	31 47.7	87 22.8	31 36.0	86 58.2	31 24.3	86 33.6	1 19.6
40	33 25.0	84 05.2	33 11.8	83 41.4	32 58.6	83 17.6	1 26.0
45	34 51.9	81 04.1	34 37.3	80 41.1	34 22.7	80 18.1	1 31.7
50	36 10.3	78 14.6	35 54.4	77 52.4	35 38.5	77 30.2	1 37.0
55	37 21.7	75 33.5	37 04.6	75 12.1	36 47.5	74 50.7	1 41.9
2 0	+ 38 26.8	72 57.8	+ 38 08.7	72 37.3	+ 37 50.6	72 16.8	1 46.3
5	39 26.5	70 26.6	39 07.4	70 07.0	38 48.3	69 47.4	1 50.3
10	40 21.1	67 58.3	40 01.1	67 39.9	39 41.1	67 21.5	1 54.0
15	41 10.9	65 31.9	40 50.1	65 14.7	40 29.3	64 57.5	1 57.3
20	41 56.2	63 07.0	41 34.6	62 51.1	41 13.0	62 35.2	2 00.1
25	42 37.0	60 42.6	42 14.8	60 28.0	41 52.6	60 13.4	2 02.6
30	+ 43 13.7	58 18.4	+ 42 51.0	58 05.2	+ 42 28.3	57 52.0	2 04.6
35	43 46.1	55 53.7	43 23.0	55 42.2	42 59.9	55 30.7	2 06.3
40	44 14.5	53 28.0	43 51.0	53 18.3	43 27.5	53 08.6	2 07.5
45	44 39.1	51 01.3	44 15.2	50 53.4	43 51.3	50 45.5	2 08.6
50	44 59.6	48 33.6	44 35.4	48 27.5	44 11.2	48 21.4	2 08.7
55	45 15.8	46 04.9	44 51.4	46 00.7	44 27.0	45 56.5	2 08.8
3 0	+ 45 27.8	43 34.7	+ 45 03.3	43 32.4	+ 44 38.8	43 30.1	2 08.3
5	45 35.6	41 02.6	45 11.1	41 02.2	44 46.6	41 01.8	2 07.5
10	45 39.1	38 28.3	45 14.7	38 30.1	44 50.3	38 31.9	2 06.4
15	45 38.2	35 52.1	45 14.0	35 55.9	44 49.8	35 59.7	2 04.6
20	45 32.5	33 13.7	45 08.7	33 19.5	44 44.9	33 25.3	2 02.5
25	45 22.1	30 33.1	44 58.8	30 40.9	44 35.5	30 48.7	2 00.1
30	+ 45 07.0	27 49.2	+ 44 44.2	27 59.0	+ 44 21.4	28 08.8	1 57.2
35	44 46.8	25 02.5	44 24.7	25 14.1	44 02.6	25 25.7	1 53.9
40	44 21.1	22 12.1	43 59.8	22 25.5	43 38.5	22 38.9	1 50.2
45	43 49.6	19 17.6	43 29.2	19 32.7	43 08.8	19 47.8	1 46.1
50	43 12.1	16 17.9	42 52.7	16 34.6	42 33.3	16 51.3	1 41.7
55	42 27.9	13 12.0	42 09.6	13 30.1	41 51.3	13 48.2	1 36.9
4 0	+ 41 35.8	9 58.0	+ 41 18.8	10 17.5	+ 41 01.8	10 37.0	1 31.5
5	40 34.8	6 33.2	40 19.3	6 54.1	40 03.8	7 15.0	1 25.7
10	39 23.4	2 54.5 W.	39 09.5	3 16.5 W.	38 55.6	3 38.5 W.	1 19.4
15	37 59.1	1 04.9 E.	37 47.1	0 41.7 E.	37 35.1	0 18.5 E.	1 12.5
20	36 17.0	5 35.5	36 07.2	5 11.0	35 57.4	4 46.5	1 04.9
25	34 06.9	11 00.4	34 00.1	10 33.8	33 53.3	10 07.2	0 56.0
30	30 58.9	18 31.8	30 57.2	17 59.9	30 55.5	17 28.0	0 44.5
Limits.	+ 25 27.3	31 41.2 E.	+ 25 20.6	31 37.1 E.	+ 25 12.2	31 30.0 E.	

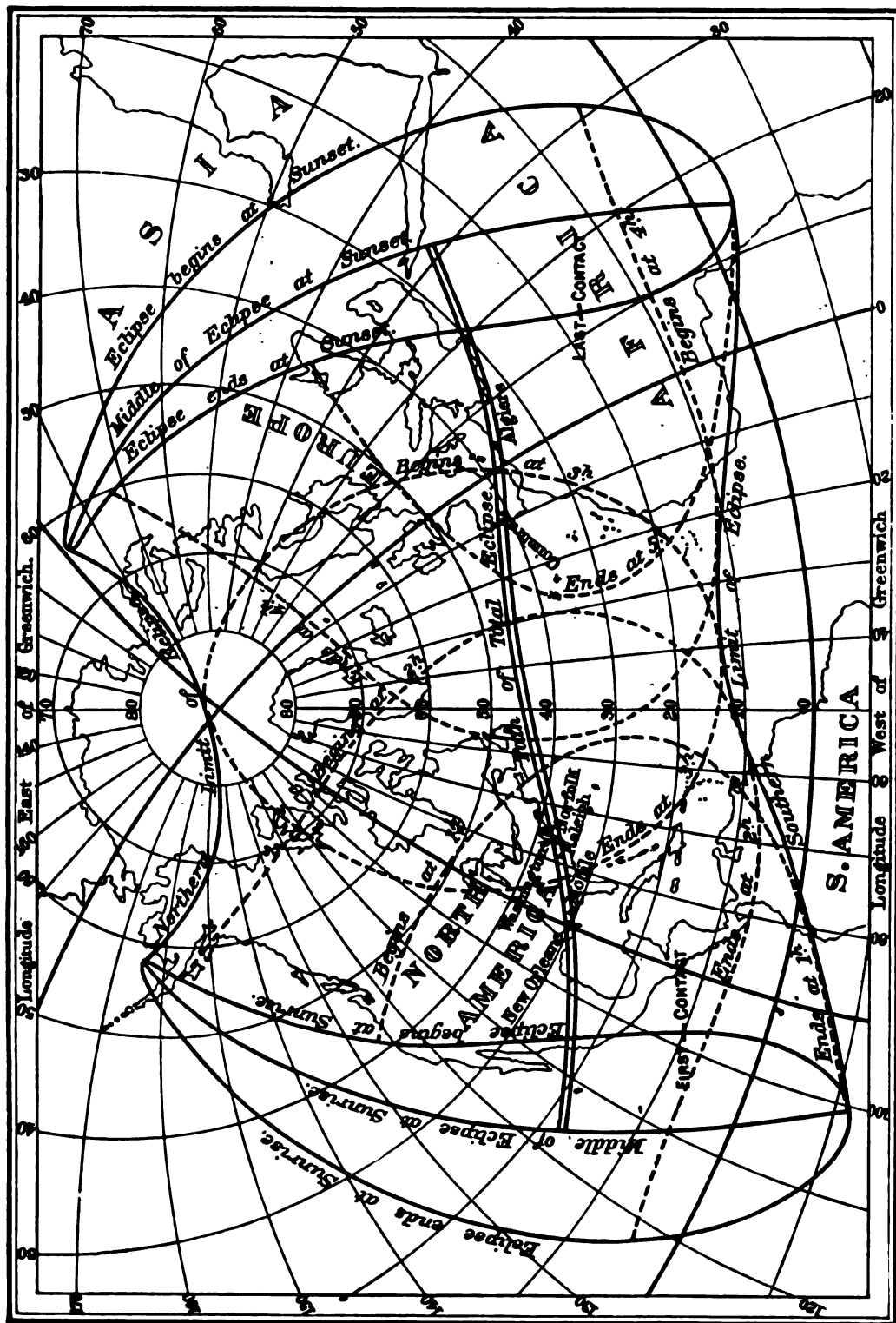
TABLE III.—(A) ECLIPSE BEGINNING.

G. M. T. May 28.	Local Civil Time, A. M.	Latitude.	Longitude.	Angle of Position from N.	G. M. T. May 28.	Local Civil Time, A. M.	Latitude.	Longitude.	Angle of Position from N.
h m	h m	° '	° '	"	h m	h m	° '	° '	"
0 25.0	6 04.5	+28 45	95 08	255.0	0 37.5	6 17.2	+37 05	95 04	245.0
	6 21.5	28 45	90 53	257.5		6 36.0	37 10	90 22	247.5
	6 35.1	28 30	87 28	260.0		6 51.8	36 58	86 25	250.0
	6 46.1	28 00	84 43	262.5		7 05.2	36 32	83 05	252.5
	6 55.1	27 13	82 28	265.0		7 16.3	35 55	80 18	255.0
0 27.5	6 23.6	+30 41	90 59	255.0	0 40.0	7 26.0	35 09	77 53	257.5
	6 38.1	30 24	87 21	257.5		7 34.7	34 17	75 42	260.0
	6 49.6	29 56	84 28	260.0		6 33.7	+38 39	91 35	245.0
	6 59.3	29 15	82 03	262.5		6 49.7	38 29	87 32	247.5
	7 07.5	28 25	80 00	265.0		7 03.9	38 08	84 02	250.0
0 30.0	6 05.9	+32 19	96 02	250.0	0 42.5	7 16.1	37 36	80 59	252.5
	6 24.3	32 27	91 26	252.5		7 26.7	36 54	78 20	255.0
	6 39.5	32 17	87 38	255.0		7 36.0	36 04	76 00	257.5
	6 51.9	31 50	84 31	257.5		7 44.4	35 10	73 54	260.0
	7 02.2	31 11	81 57	260.0	0 45.0	6 47.4	+40 00	88 46	245.0
0 32.5	7 11.0	30 24	79 45	262.5		7 02.2	39 40	85 05	247.5
	7 18.8	29 31	77 48	265.0		7 15.0	39 12	81 53	250.0
	6 23.4	+34 07	92 16	250.0		7 26.4	38 34	79 02	252.5
	6 39.7	34 00	88 12	252.5		7 36.6	37 47	76 29	255.0
0 35.0	6 53.1	33 39	84 51	255.0		7 45.6	36 54	74 13	257.5
	7 04.2	33 05	82 04	257.5	0 47.5	7 53.6	35 59	72 13	260.0
	7 13.8	32 18	79 41	260.0		6 59.2	+41 11	86 27	245.0
	5 57.3	+35 15	99 25	245.0		7 13.1	40 47	82 58	247.5
	6 20.3	35 38	93 41	247.5		7 25.5	40 12	79 52	250.0
0 37.5	6 38.5	35 39	89 07	250.0		7 36.5	39 29	77 07	252.5
	6 53.2	35 22	85 27	252.5		7 46.3	38 39	74 41	255.0
	7 05.2	34 51	82 27	255.0		7 54.9	37 44	72 31	257.5
	7 15.5	34 10	79 53	257.5		8 02.6	+36 45	70 36	260.0
	7 24.5	+33 20	77 37	260.0					

TABLE III.—(B) ECLIPSE ENDING.

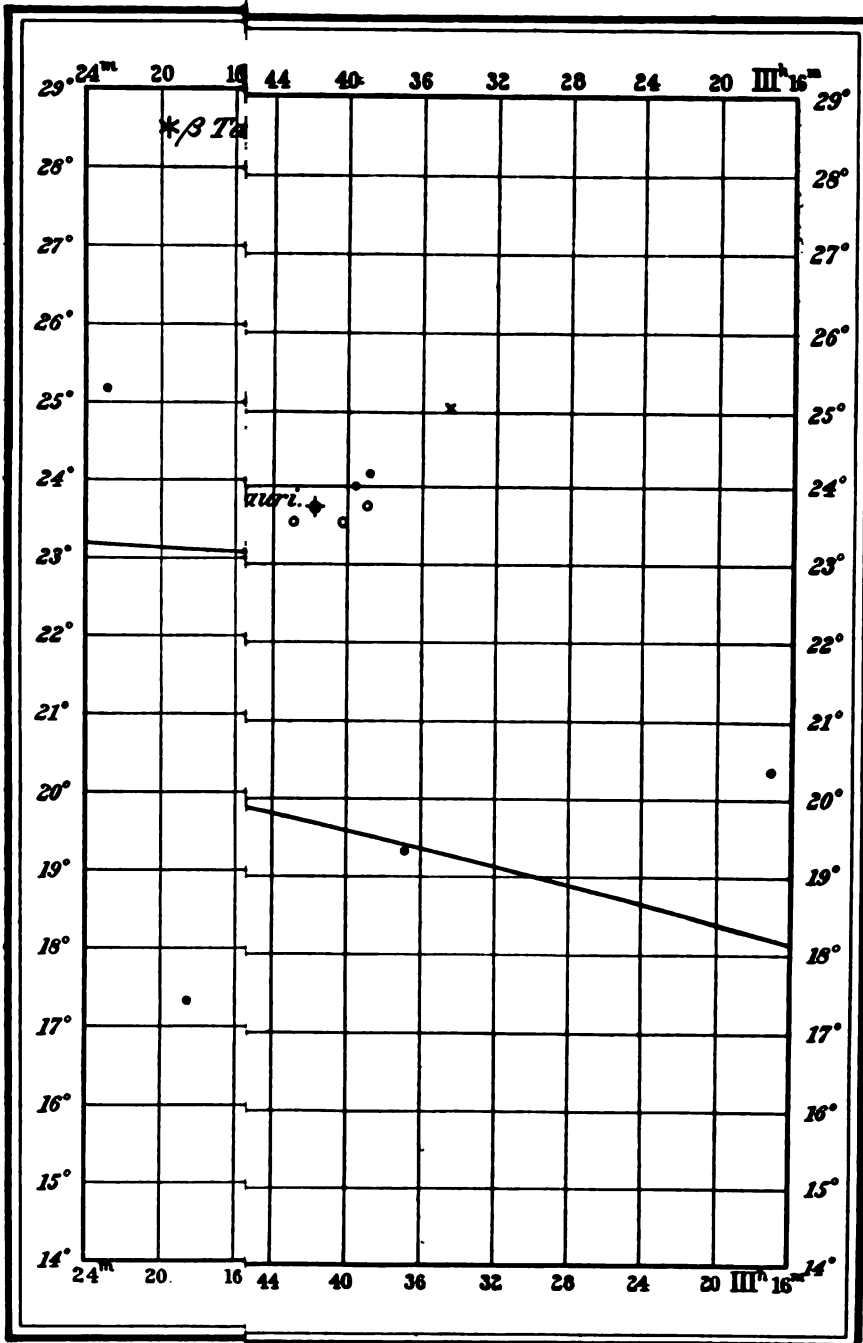
2 40.0	8 44.7	+26 50	88 50	70.0	3 00.0	9 24.1	+35 27	83 59	80.0
	8 33.9	28 53	91 31	75.0		9 15.7	37 57	86 05	85.0
	8 23.1	31 01	94 13	80.0		9 54.7	+31 24	77 34	70.0
	8 12.3	33 14	96 55	85.0		9 46.5	33 55	79 38	75.0
2 45.0	8 59.5	+27 57	86 23	70.0	3 05.0	9 38.4	36 24	81 39	80.0
	8 49.3	30 05	88 55	75.0		9 30.6	38 55	83 36	85.0
	8 39.1	32 17	91 28	80.0		10 08.0	+32 16	75 30	70.0
	8 29.1	34 36	93 59	85.0		10 00.1	34 41	77 28	75.0
2 50.0	9 13.7	+28 59	84 05	70.0	3 10.0	9 52.6	37 11	79 21	80.0
	9 04.1	31 10	86 28	75.0		9 45.3	39 48	81 11	85.0
	8 54.5	33 27	88 52	80.0		10 21.1	+32 57	73 29	70.0
	8 45.1	35 50	91 14	85.0		10 13.7	35 23	75 20	75.0
2 55.0	9 27.7	+29 55	81 50	70.0	3 15.0	10 06.6	37 56	77 06	80.0
	9 18.5	32 10	84 07	75.0		9 59.9	40 34	78 47	85.0
	9 09.5	34 31	86 23	80.0		10 34.1	+33 31	71 28	70.0
	9 00.6	36 57	88 36	85.0		10 27.2	36 01	73 12	75.0
3 00.0	9 41.3	+30 47	79 41	70.0	3 20.0	10 20.5	38 37	74 53	80.0
	9 32.7	+33 03	81 49	75.0		10 14.3	+41 17	76 25	85.0

CHART I.—TOTAL ECLIPSE OF THE SUN, MAY 28, 1900.



NOTE.—The hours of beginning and ending are expressed in Greenwich Mean Time.

CHART II.



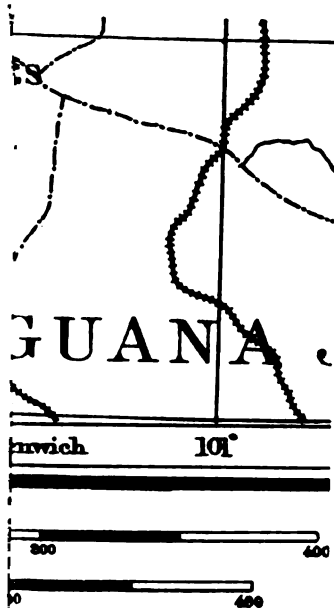


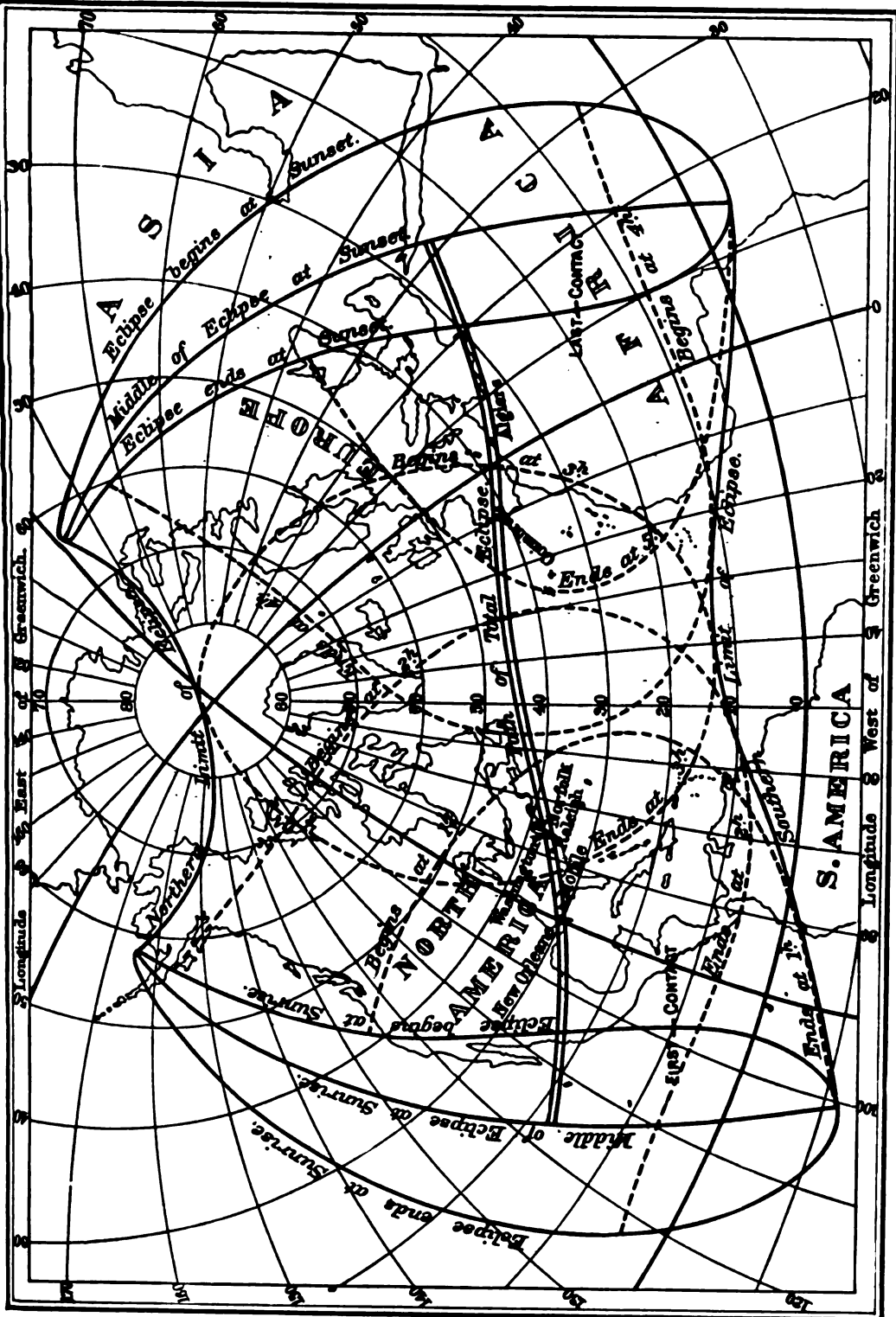
TABLE III.—(A) ECLIPSE BEGINNING.

G. M. T. May 28.	Local Civil Time, A. M.	Latitude.	Longitude.	Angle of Position from N.	G. M. T. May 28.	Local Civil Time, A. M.	Latitude.	Longitude.	Angle of Position from N.
h m	h m	°	°	"	h m	h m	°	°	°
0 25.0	6 04.5	+28 45	95 08	255.0	0 37.5	6 17.2	+37 05	95 04	245.0
	6 21.5	28 45	90 53	257.5		6 36.0	37 10	90 22	247.5
	6 35.1	28 30	87 28	260.0		6 51.8	36 58	86 25	250.0
	6 46.1	28 00	84 43	262.5		7 05.2	36 32	83 05	252.5
	6 55.1	27 13	82 28	265.0		7 16.3	35 55	80 18	255.0
0 27.5	6 23.6	+30 41	90 59	255.0		7 26.0	35 09	77 53	257.5
	6 38.1	30 24	87 21	257.5		7 34.7	34 17	75 42	260.0
	6 49.6	29 56	84 28	260.0	0 40.0	6 33.7	+38 39	91 35	245.0
	6 59.3	29 15	82 03	262.5		6 49.7	38 29	87 32	247.5
	7 07.5	28 25	80 00	265.0		7 03.9	38 08	84 02	250.0
0 30.0	6 05.9	+32 19	96 02	250.0		7 16.1	37 36	80 59	252.5
	6 24.3	32 27	91 26	252.5		7 26.7	36 54	78 20	255.0
	6 39.5	32 17	87 38	255.0		7 36.0	36 04	76 00	257.5
	6 51.9	31 50	84 31	257.5		7 44.4	35 10	73 54	260.0
	7 02.2	31 11	81 57	260.0	0 42.5	6 47.4	+39 00	88 46	245.0
	7 11.0	30 24	79 45	262.5		7 02.2	39 40	85 05	247.5
	7 18.8	29 31	77 48	265.0		7 15.0	39 12	81 53	250.0
0 32.5	6 23.4	+34 07	92 16	250.0		7 26.4	38 34	79 02	252.5
	6 39.7	34 00	88 12	252.5		7 36.6	37 47	76 29	255.0
	6 53.1	33 39	84 51	255.0		7 45.6	36 54	74 13	257.5
	7 04.2	33 05	82 04	257.5		7 53.6	35 59	72 13	260.0
	7 13.8	32 18	79 41	260.0	0 45.0	6 59.2	+41 11	86 27	245.0
0 35.0	5 57.3	+35 15	99 25	245.0		7 13.1	40 47	82 58	247.5
	6 20.3	35 38	93 41	247.5		7 25.5	40 12	79 52	250.0
	6 38.5	35 39	89 07	250.0		7 36.5	39 29	77 07	252.5
	6 53.2	35 22	85 27	252.5		7 46.3	38 39	74 41	255.0
	7 05.2	34 51	82 27	255.0		7 54.9	37 44	72 31	257.5
	7 15.5	34 10	79 53	257.5		8 02.6	+36 45	70 36	260.0
	7 24.5	+33 20	77 37	260.0					

TABLE III.—(B) ECLIPSE ENDING.

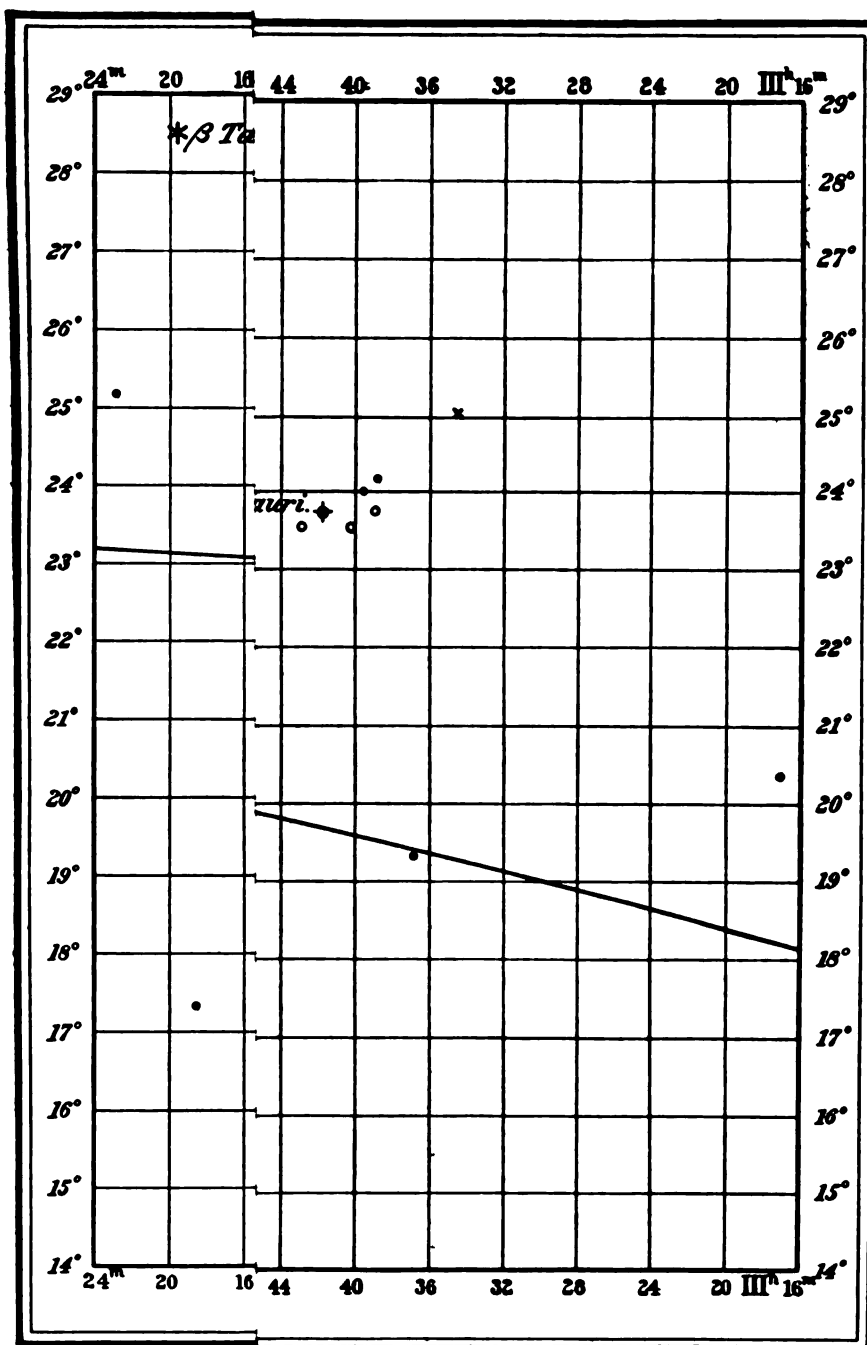
2 40.0	8 44.7	+26 50	88 50	70.0	3 00.0	9 24.1	+35 27	83 59	80.0
	8 33.9	28 53	91 31	75.0		9 15.7	37 57	86 05	85.0
	8 23.1	31 01	94 13	80.0	3 05.0	9 54.7	+31 24	77 34	70.0
	8 12.3	33 14	96 55	85.0		9 46.5	33 55	79 38	75.0
2 45.0	8 59.5	+27 57	86 23	70.0		9 38.4	36 24	81 39	80.0
	8 49.3	30 05	88 55	75.0		9 30.6	38 55	83 36	85.0
	8 39.1	32 17	91 28	80.0	3 10.0	10 08.0	+32 16	75 30	70.0
	8 29.1	34 36	93 59	85.0		10 00.1	34 41	77 28	75.0
2 50.0	9 13.7	+28 59	84 05	70.0		9 52.6	37 11	79 21	80.0
	9 04.1	31 10	86 28	75.0		9 45.3	39 48	81 11	85.0
	8 54.5	33 27	88 52	80.0	3 15.0	10 21.1	+32 57	73 29	70.0
	8 45.1	35 50	91 14	85.0		10 13.7	35 23	75 20	75.0
2 55.0	9 27.7	+29 55	81 50	70.0		10 06.6	37 56	77 06	80.0
	9 18.5	32 10	84 07	75.0		9 59.9	40 34	78 47	85.0
	9 09.5	34 31	86 23	80.0	3 20.0	10 34.1	+33 31	71 28	70.0
	9 00.6	36 57	88 36	85.0		10 27.2	36 01	73 12	75.0
3 00.0	9 41.3	+30 47	79 41	70.0		10 20.5	38 37	74 53	80.0
	9 32.7	+33 03	81 49	75.0		10 14.3	+41 17	76 25	85.0

CHART I.—TOTAL ECLIPSE OF THE SUN, MAY 28, 1900.



NOTE.—The hours of beginning and ending are expressed in Greenwich Mean Time.

CHART II.



UNIVERSITY OF MICHIGAN
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